We claim:

1. A process for preparing 4-vinylcyclohexene, which comprises the steps

(A) providing an n-butane-containing feed gas stream,

(B) feeding the n-butane-containing feed gas stream into at least one dehydrogenation zone and dehydrogenating n-butane to butadiene to give a product stream comprising butadiene, n-butane, possibly 1-butene and 2-butene and possibly water vapor and other secondary constituents,

(C) feeding the product stream from dehydrogenation, if appropriate after separating off water vapor and secondary constituents, into a dimerization zone and catalytically dimerizing butadiene to give a product stream comprising 4-vinylcyclohexene, n-butane and possibly 1-butene, 2-butene and unreacted butadiene, and

(D) separating off 4-vinylcyclohexene from the product stream from the dimerization and recirculating n-butane and possibly 1-butene, 2-butene and unreacted butadiene to the dehydrogenation zone.

2. A process as claimed in claim 1, wherein the provision of the n-butane-containing dehydrogenation feed stream comprises the steps

(A1) providing a liquefied petroleum gas (LPG) stream,

(A2) separating off propane and, if appropriate, methane, ethane and pentanes from the LPG stream to give a stream comprising butanes,

(A3) separating off isobutane from the stream comprising butanes to give the n-butane-containing feed gas stream and, if desired, isomerizing the isobutane which has been separated off to give an n-butane/isobutane mixture and recirculating the n-butane/isobutane mixture to the isobutane separation step.

3. A process as claimed in claim 1 or 2, wherein the dehydrogenation of n-butane to butadiene is carried out as an autothermal catalytic dehydrogenation.

4. A process as claimed in claim 1 or 2, wherein the dehydrogenation of n-butane to butadiene comprises the steps

(B1) feeding the n-butane-containing feed gas stream into a first dehydrogenation zone and catalytically, nonoxidatively dehydrogenating n-butane to 1-butene, 2-butene and possibly butadiene to give a product gas stream comprising butadiene, n-butane, 1-butene, 2-butene and possibly secondary constituents,

(B2) feeding the product gas stream comprising n-butane, 1-butene, 2-butene, possibly butadiene and possibly secondary constituents into a second dehydrogenation zone and oxidatively dehydrogenating 1-butene and 2-butene to butadiene to give a product gas

stream comprising butadiene, n-butane, water vapor and possibly secondary constituents.

5. A process as claimed in claim 4, wherein the catalytic, nonoxidative dehydrogenation of n-butane to 1-butene, 2-butene and butadiene is carried out as an autothermal dehydrogenation.

6. A process as claimed in any of claims 1 to 4, wherein water vapor and secondary constituents from the group consisting of hydrogen, carbon monoxide, carbon dioxide, nitrogen, methane, ethane, ethene, propane and propene are separated off from the product stream from the dehydrogenation prior to the dimerization.

7. A process for preparing ethylbenzene or styrene comprising the steps (A), (B), (C) and (D) as defined in any of claims 1 to 6 and the additional step

(E) feeding 4-vinylcyclohexene into a further dehydrogenation zone and catalytically dehydrogenating it to ethylbenzene or oxidatively dehydrogenating it in the presence of oxygen to give styrene.

8. A process for preparing styrene comprising the steps

(A) providing an n-butane-containing feed gas stream,

(F') feeding the n-butane-containing feed gas stream and a 4-vinylcyclohexene-containing gas stream into a dehydrogenation zone and jointly dehydrogenating n-butane and 4-vinylcyclohexene in the presence of oxygen to give a product stream comprising

styrene, butadiene, n-butane, 1-butene, 2-butene, possibly ethylbenzene and further secondary constituents,

(G') separating off styrene and, if applicable, ethylbenzene and further high-boiling secondary constituents from the product stream from the dehydrogenation,

(H') feeding the stream comprising butadiene, n-butane, 1-butene and 2-butene into a dimerization zone and catalytically dimerizing butadiene to give a product stream comprising 4-vinylcyclohexene, n-butane, 1-butene, 2-butene and possibly unreacted butadiene,

(I') isolating the 4-vinylcyclohexene-containing gas stream from the product stream from the dimerization and feeding it into the dehydrogenation zone.

9. A process as claimed in claim 8, wherein the joint dehydrogenation of n-butane and 4-vinylcyclohexene is carried out in the presence of a dehydrogenation catalyst comprising a noble metal of transition group VIII together with, if desired, one or more elements of main groups I and/or II, one or more elements of main group III including the lanthanides and actinides and/or one or more elements of main groups III and/or IV on a support.